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# Copper Partitioning in $CO_2$-Bearing Melt-Vapor-Brine Systems

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Analysis of fluid and melt inclusions from arc-related intrusions and porphyry copper deposits (PCD) reveal that many fluid inclusions from PCD are typically characterized by $X_{CO2} < 0.10$, which is lower than that found in volatile phases exsolved from shallow (e.g., 5 to 10 km), arc magmas, in general ($X_{CO2}$ up to order ~ 0.45). This disparity remains to be resolved.

The efficiency with which copper can be removed from arc magmas into exsolving volatile phases is a function of the competition between crystalline phases (± liquid sulphides), and the exsolving vapor ± brine. Experiments in melt-vapor-brine systems permit the investigation of the partitioning of copper between silicate melts and volatile phases under magmatic conditions. However, the effect of $CO_2$ on melt-volatile phase equilibria relevant to the formation of PCD has remained unconstrained. In this study, the partitioning of copper in $CO_2$-bearing, sulfur-free and sulfur-bearing, experiments may provide additional insights into copper partitioning and the generation of PCD.

We present results from experiments performed at 800 °C and 100 MPa in $CO_2$-bearing, sulfur-free and sulfur-bearing melt-vapor-brine systems with $X_{CO2}$ (bulk vapor ± brine) = 0.10 and 0.38. The compositions of vapor and brine inclusions and run-product glasses were used as proxies for the compositions of the magmatic phases. The salinities of vapor inclusions that nucleated clathrate ($CO_2$ ± $H_2S$ clathrate) upon cooling were determined via Raman analysis and microthermometry [1]. The partitioning of copper between brine and vapor ($D^{b/v}_{Cu}(\pm 2\sigma)$) increases from 25(±6) to 100 (±30) for sulfur-free experiments and from 11(±3) to 95(±23) for sulfur-bearing experiments, as $X_{CO2}$ is increased from 0.10 to 0.38. The partitioning of copper between vapor and melt increases with the addition of sulfur at $X_{CO2} = 0.10$: ($D^{v/m}_{Cu}(\pm 2\sigma)$) = 9.6(±3.3) (sulfur-free, metaluminous melt); 18(±8) (sulfur-bearing, peralkaline melt); and 30(±11) (sulfur-bearing, metaluminous melt). These values are to be contrasted with ($D^{v/m}_{Cu}(\pm 2\sigma)$) = 2(±0.8) at $X_{CO2} = 0.38$ (the effect of sulfur cannot be distinguished at this mole fraction of $CO_2$). These data demonstrate that changes in the salinity of the vapor and brine, which are controlled by changes in $X_{CO2}$, play a major role in controlling copper partitioning in sulfur-free, $CO_2$-bearing systems. Sulfur-bearing experiments demonstrate that magmatic vapors are enriched in copper in the presence of sulfur at low $X_{CO2}$. However, the enrichment of copper in the magmatic vapor is suppressed for sulfur-bearing systems at high $X_{CO2}$. These data indicate that the efficient removal of copper from silicate melts into vapor ± brine is mitigated by high concentrations of $CO_2$. Furthermore, the poisoning effect of $CO_2$ is more pronounced for sulfur-bearing volatile phases. As a result, high concentrations of $CO_2$ may play a negative role in the formation of PCD.

[1] Fall et al. (2011) *Geochimica et Cosmochimica Acta* **75**, 951-964.